Claims

1. A machine-implemented method for a progressive optical device, comprising:

defining a triangulation grid over a design field;

receiving a set of parameters, including a desired power distribution function, a power deviation weight function, and an astigmatism weight function, the functions being defined over the design field;

defining a base surface over the design field;

solving a linearized variational partial differential equation on the triangulation grid in terms of the power distribution function, the power deviation weight function, and the astigmatism weight function, to produce perturbations from the base surface;

combining the perturbations with the base surface to produce output data representing a surface of the optical element.

2. The method of claim 1 where the optical element is a progressive ophthalmic lens.

3. The method of claim 1 further comprising outputting the output data to a medium.

4. The method of claim 3 where the medium is a digital storage medium.

5. The method of claim 3 further comprising fabricating the optical device from the output data.

6. The method of claim 5 where fabricating the medium comprises grinding a lens blank.

7. The method of claim 1 where the power deviation weight function represents relative importances of the power distribution function over different areas of the design field.

8. The method of claim 7 where the power deviation weight function is approximately piecewise linear.

9. The method of claim 8 where the power deviation weight function is smoothed.

10. The method of claim 1 where the astigmatism weight function represents relative importances of astigmatism over different areas of the design field.

11. The method of claim 10 where the astigmatism weight function is approximately piecewise linear.

12. The method of claim 11 where the astigmatism weight function is smoothed.

13. The method of claim 1 further comprising dividing the design field into a plurality of regions.

14. The method of claim 13 where the power distribution function is approximately constant over at least some of the regions.

15. The method of claim 13 where the power deviation function is approximately constant over at least some of the regions

16. The method of claim 13 where the astigmatism function is approximately constant over at least some of the regions

17. The method of claim 13 where the regions include at least a far-view region, a near-view region, and a corridor region.

18. The method of claim 1 where the base surface is non-planar.

19. The method of claim 18 where the base surface is spherical.

20. The method of claim 18 where the base surface is toric.

21. The method of claim 1 where the equation includes a linear term and a bilinear term.

22. The method of claim 21 where the equation has the form $B(\delta,v)=L(\delta)$, where L is a linear functional of a test function δ, and B is a bilinear form depending on δ and on a perturbation function v.

22.1. The method of claim 21 where B and L have substantially the forms

$$B(\delta,v) = \int \; [2(\alpha + \beta)H_{u_0}(\delta)H_{u_0}(v) - \alpha K_{u_0}(\delta,v)]dxdy$$

$$L(\delta) = \int \; \left[\alpha K_{u_0}(\delta,u_0) + 2\left(\beta P - \frac{\alpha+\beta}{R}\right)H_{u_0}(\delta)\right]dxdy$$

23. The method of claim 1 where the equation is solved as superpositions of a set of overlapping splines.

24. The method of claim 23 where the splines are quadratic.

25. The method of claim 23 where each spline has compact support over a different subset of the grid elements.

26. The method of claim 23 where some of the splines have a support partially outside the design field.

27. The method of claim 1 where the boundary conditions of the equation are less than fully clamped.

28. The method of claim 27 where the boundary conditions are free.

29. The method of claim 1 where the triangulation grid is a uniform type II grid.

30. where a size of the grid is one of the received parameters.

31. The method of claim 1 further comprising evaluating the output data.

32. The method of claim 31 where evaluating includes interpolating the output data with a set of splines having at least second-order derivatives at points corresponding to points of the grid.

33. A machine-readable medium bearing instructions for causing a digital computer to execute the method of claim 1.

34. A machine-implemented method for a progressive optical device having integrated astigmatism correction, comprising:

defining a triangulation grid over a design field;

receiving a set of parameters, including a desired astigmatism correction, a desired power distribution function, a power deviation weight function, and an undesired-astigmatism weight function, the functions being defined over the design field;

defining over the design field a base surface that includes the desired astigmatism correction;

solving a variational equation on the triangulation grid in terms of the power distribution function, the power deviation function, and the astigmatism function, to produce perturbations from the base surface;

combining the perturbations with the base surface to produce output data representing a surface of the optical element.

35. The method of claim 34 where the optical element is a progressive ophthalmic lens with power correction and astigmatism correction in a single surface.

36. The method of claim 35 where the single surface is a back surface.

37. The method of claim 34 further comprising outputting the output data to a medium.

38. The method of claim 37 where the medium is a digital storage medium.

39. The method of claim 37 further comprising fabricating the optical device in a lens blank from the output data by altering only the single surface..

40. The method of claim 37 where fabricating the medium comprises grinding only the single surface of a lens blank.

41. The method of claim 34 where the power deviation function represents relative importances of the power distribution function over different areas of the design field.

42. The method of claim 34 where the astigmatism function represents relative importances of undesired astigmatism over different areas of the design field.

43. The method of claim 34 where the base surface is toric.

44. The method of claim 34 where the equation includes a linear term and a bilinear term.

45. The method of claim 44 where the equation has the form $B'(\delta,v)=L'(\delta)$, where L' is a linear functional of a test function δ and B' is a bilinear form depending on δ and on a perturbation function v.

46. The method of claim 45 where B' and L' have substantially the forms

$$B'(\delta,v) = \int [2(\alpha + \beta)H_{u_0}(v)H_{u_0}(\delta) - \alpha K_{u_0}(\delta,v)]dxdy$$
$$L'(\delta) = \int 2\beta(P - H_{u_0}(u_0))H_{u_0}(\delta)dxdy$$

47. The method of claim 34 where the equation is solved in terms of a set of splines.

48. The method of claim 47 where the splines are piecewise quadratic.

49. The method of claim 47 where each spline has compact support over a different subset of the grid elements.

50. The method of claim 34 where the boundary conditions of the equation are less than fully clamped.

51. The method of claim 50 where the boundary conditions are free.

52. The method of claim 34 where the triangulation grid is a uniform type II grid.

53. A machine-readable medium bearing instructions for causing a digital computer to execute the method of claim 34.

54. An optical device having multiple different magnifying powers and a desired astigmatism correction in the same optical surface.

55. The device of claim 54 where the device is a lens having a front surface and a back surface.

56. The device of claim 54 where the different magnifying powers lie in two different regions of the device, and the astigmatism in both regions is substantially the desired astigmatism correction.

57. The device of claim 56 where the device includes a third region having a magnifying power between those of the two regions.

58. The device of claim 56 where the astigmatism outside the two regions differs from the desired astigmatism correction.

59. A progressive ophthalmic lens having front and back surfaces, the lens having at least two different desired magnifying powers and a desired astigmatism correction all in one of the surfaces of the lens.

60. The lens of claim 59 where the one surface is the back surface.

61. The lens of claim 59 where the lens comprises:

a far-view region where the one surface has a first of the desired power corrections and the desired astigmatism correction;

a near-view region where the one surface has a second of the desired power corrections and the desired astigmatism correction.

62. The lens of claim 61 where the lens further comprises a corridor region where the one surface has a variable power between the first and second power corrections and the desired astigmatism correction.

63. The lens of claim 62 where the corridor region lies between the far-view region and the near-view region.

64. The lens of claim 59 where the other surface has substantially no astigmatism.

65. The lens of claim 59 where the maximum deviation of the total astigmatism in the lens does not exceed about 75% of the difference between the magnifying powers.

66. Ophthalmic spectacles comprising a frame and a pair of lenses having front and back surfaces, each lens having at least two different desired magnifying powers and at least one of the lenses further including a desired astigmatism correction in the same surface of the lens as the magnifying powers.

67. The spectacles of claim 66 where both of the lenses include a desired astigmatism correction in the same surface of the lens as the magnifying powers.

68. The spectacles of claim 66 where the same surface is a back surface of the lens.